BLOCKCHAIN DECISION PATH: "WHEN TO USE BLOCKCHAIN?" – "WHICH BLOCKCHAIN DO YOU MEAN?"

Abstract

A wide range of socioeconomic hopes are pinned on the transformative power of blockchain technologies. However, blockchain databases have noticeable drawbacks (i.e., scalability, capacity, latency, privacy) that clearly indicate that blockchain is not a silver bullet for all problems. The application and selection of blockchain need to be carefully assessed, depending on the problem and use case at hand. To support IT decision-makers, we develop a ten-step decision path that can help determine whether or not the application of blockchain is justified and, if so, which kind of blockchain to use. We apply this decision path to the case of the maritime shipping industry, and develop a blockchain prototype for this case.

Keywords

Blockchain, Decision Path, Supply Chain Management, Smart Contract Prototype, Decision-Making, Use-Case Identification

THE PITFALLS AND PROMISES OF BLOCKCHAIN

Inefficient business processes due to outdated IT infrastructure provide prolific environments for substantial change and improvement.[1] The persistence of such issues is clearly exemplified by but not limited to the maritime shipping industry, which continues to copy and store important documents as paper-based hard copies, which are then distributed among stakeholders along the supply chain. The manual nature of such administrative processes makes them obviously inefficient and highly prone to human error. As such, these basic organizational tasks waste resources and frequently lead to substantial fines.[2] Large shipping companies like Mærsk and DanPilot, as well as national and international administrative authorities like the International Maritime Organization of the United Nations complain about these inefficient processes but have done little to remedy them.

Recently, blockchain technologies have attracted considerable attention as an immutable distributed ledger technology capable of sharing information transparently and enabling reliable transactions among unfamiliar entities.[3] While initially research discussed the propositions of blockchain technologies for the financial industry, supply chains have emerged as the most promising sector. Industry estimates that US$1.5 to 2.1 billion will be spent on blockchain technologies to enhance traceability, enhance transparency and save costs.[4, 5] A recent study concluded that value realization was happening faster in provenance tracking than in banking & financial services.[6] Accordingly, CIOs in the maritime shipping industry have pinned great hopes on the potential of blockchain to reshape the economy and to potentially reduce transaction costs.[7] As such, executives in the maritime shipping industry harbor the hope that blockchain technologies may present a feasible solution for facilitating operations, avoiding fees, and improving regulatory compliance. Leading shipment companies like Mærsk A/S, APL Ltd., Hyundai Merchant Marine Co., and Samsung SDS Co. have already invested heavily in blockchain technologies as a means of replacing the paper-laden processes; they hope that using blockchain

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[1] Grover, V., Jeong, S. R., Kettinger, W. J., and Teng, J. T. C. 1995. "The Implementation of Business Process Reengineering," Journal of Management Information Systems (12:1), pp. 109-144.

[2] Pittalis, E., Sleiman, T., Washington, T., and Leech, J. 2018. "Feature: No Exceptions from Insurers in 2020 for Imo Non-Compliance." Retrieved June 13, 2018, 2018, from https://www.platts.com/latest-news/shipping/london/feature-no-exceptions-from-insurers-in-2020-for-26884390

[3] Beck, R., Müller-Bloch, C., and Leslie King, J. 2018. "Governance in the Blockchain Economy: A Framework and Research Agenda," *Forthcoming in: Journal of the Association for Information Systems*.

[4] Capgemini. 2018. "Does Blockchain Hold the Key to a New Age of Supply Chain Transparency and Trust? How Organizations Have Moved from Blockchain Hype to Reality." Retrieved November 24, 2018, 2018, from https://www.capgemini.com/wp-content/uploads/2018/10/Digital-Blockchain-in-Supply-Chain-Report.pdf

[5] Deloitte. 2018. "Blockchain and the Five Vectors of Progress." Retrieved November 24, 2018, 2018, from https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/value-of-blockchain-applications-interoperability.html

[6] Gupta, S. 2018. "HFS Top 10 Blockchain Platforms 2018." Retrieved November 24, 2018, 2018, from https://www.hfsresearch.com/top-10-reports/hfs-top-10-blockchain-platforms-2018

[7] Iansiti, M., and Lakhani, K. R. 2017. "The Truth About Blockchain," *Harvard Business Review*, (1).

will generate an additional US$1 trillion in global trade.[8] However, designing applications to determine what kind of blockchain and which configuration to use has thus far presented a major obstacle for decision-makers and system architects. While there are frameworks to address these questions and to comprehensively explain the technical design[9] and business application considerations,[10] these frameworks still fail to address the decision-makers' common questions about whether a blockchain solution is feasible, and if so, what kind of blockchain system should be implemented. Each blockchain implementation requires a carefully considered decision based on the characteristics of the individual use case.[11] Our experience working as blockchain consultants on projects for several years in both the private and public sectors, as well as the knowledge and understanding gained through heading the European Blockchain Center, has allowed us to inform a managerial framework that we developed using a design science research approach.

To inform the pressing questions associated with blockchain implementation in general and specifically in the context of the maritime shipping industry, we present and apply a ten-step decision path that helps determine if a blockchain database is actually applicable, decide what kind of blockchain solution would be most suitable, and explain the related system design elements. We illustrate this approach by developing a blockchain prototype for the maritime shipping industry, which we supported with stakeholder interviews with the shipping company DanPilot, as well as with the regulatory and enforcing the Danish Maritime Authority. DanPilot is a medium-sized Danish pilotage company that employs about 160 pilots and 90 boatmen who manage approximately 20,000 pilotages a year. As such, we offer practitioners an urgently needed decision path that considers the unique attributes of different blockchains (see Appendix A) on the basis of an actual blockchain-use case example.

This framework should generally help decision-makers, not only to conclude on whether or not to use blockchain but also which kind of blockchain technology to consider. However, we are not able to describe the particularities of each situation. Thus, practitioners are often faced with more complex and potentially paradoxical business and design trade-offs.[12] The blockchain decision path should help to

[8] Park, K. 2018. "Blockchain Is About to Revolutionize the Shipping Industry." Retrieved September 28, 2018, 2018, from https://www.bloomberg.com/news/articles/2018-04-18/drowning-in-a-sea-of-paper-world-s-biggest-ships-seek-a-way-out

[9] Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., and Rimba, P. 2017. "A Taxonomy of Blockchain-Based Systems for Architecture Design," *2017 IEEE International Conference on Software Architecture (ICSA)*, Gothenburg, Sweden. IEEE, pp. 243-252.

[10] Glaser, F. 2017. "Pervasive Decentralisation of Digital Infrastructures: A Framework for Blockchain Enabled System and Use Case Analysis," *50th Hawaii International Conference on System Sciences (HICSS 2017)*, Waikoloa, Hawaii, USA. IEEE.

[11] Risius, M., and Spohrer, K. 2017. "A Blockchain Research Framework: What We (Don't) Know, Where We Go from Here, and How We Will Get There," *Business & Information Systems Engineering* (59:6), pp. 385-409.

[12] Andriopoulos, C., and Lewis, M. W. 2010. "Managing Innovation Paradoxes: Ambidexterity Lessons from Leading Product Design Companies," Long Range Planning (43:1), pp. 104-122.

systematically assess the feasibility of a potential blockchain solution.

Blockchain as a Potential Solution for Economic Inefficiencies

Economically challenging times are often a powerful driver for companies to reevaluate their processes and identify inefficiencies as well as missed opportunities. In the aftermath of the 2008 financial crisis, the maritime shipping industry, like many others, has had some extremely difficult years financially due to factors like shrinking demand, excessive shipping capacity, and expensive credit.[13] Out of necessity, the affected companies have sought larger, better, and more price-sensitive solutions at sea to improve their operational efficiencies and overcome economic impediments.[14]

These challenging circumstances are not unique to the maritime shipping industry. Supply chains in general are a prominent use case for blockchain technologies since they struggle with legacy systems, paper-based processes, experience strong price pressure, and rely heavily on integrated systems and information. Thus, the blockchain decision path is not limited to this specific case but is applicable to various business contexts.

This study is conducted in the context of the Danish maritime shipping industry, which is representative for the general maritime industry for several reasons. Denmark is among the world's leading shipping nations in terms of owned and operating tonnage.[15] As the 6th largest shipping nation, Denmark has been devoting significant effort to overcoming economic obstacles and staying competitive by investing heavily in IT-based solutions.[16] A comprehensive analysis of operational processes has identified a major inefficiency, in that most of the data output from maintenance, logs, crew, machinery, and monitoring, is gathered and stored locally onboard the vessel for insurance purposes. To make matters worse, most of these data are stored in paper format. For administrative and regulatory purposes these papers are then duplicated multiple times and distributed to crews, vessels, shipping companies, and authorities. These processes rely heavily on manual labor in disparate organizations, leading to incoherent and dispersed data storage systems. However, any compliance failures that arise within these processes, frequently lead to multimillion-dollar claims, due to the delayed discharge of cargo, additional docking fees, or tied-up resources in the form of immobilized carriers, for example. Furthermore, these fragmented and often inconsistent databases necessitate public access, since they are often consulted during legal disputes. As insufficient as they are, these documents in the authorities'

[13] Economist, T. 2016. "The Global Shipping Industry's Woes." Retrieved June 11, 2018, from https://www.economist.com/graphic-detail/2016/09/09/the-global-shipping-industrys-woes

[14] Sanders, U., Faeste, L., Riedl, J., Egloff, C., Lee, D., Kloppsteck, L., Kolind, J., and Italino, J. 2015. "Battling Overcapacity in Container Shipping," Boston Consulting Group.

[15] Danish Ministry of Industry, B. a. F. A. 2018b. "Maritime Denmark a Global Power Hub. The Government's Plan for Growth in the Danish Maritime Sector Positions the Country to Become a Global Maritime Hub by 2025.," Copenhagen, DK, pp. 1-24.

[16] Danish Ministry of Industry, B. a. F. A. 2018a. "The Danish Government Launches the Technology Pact," Danish Ministry of Industry, Business and Financial Affairs, Copenhagen, DK, p. 1.

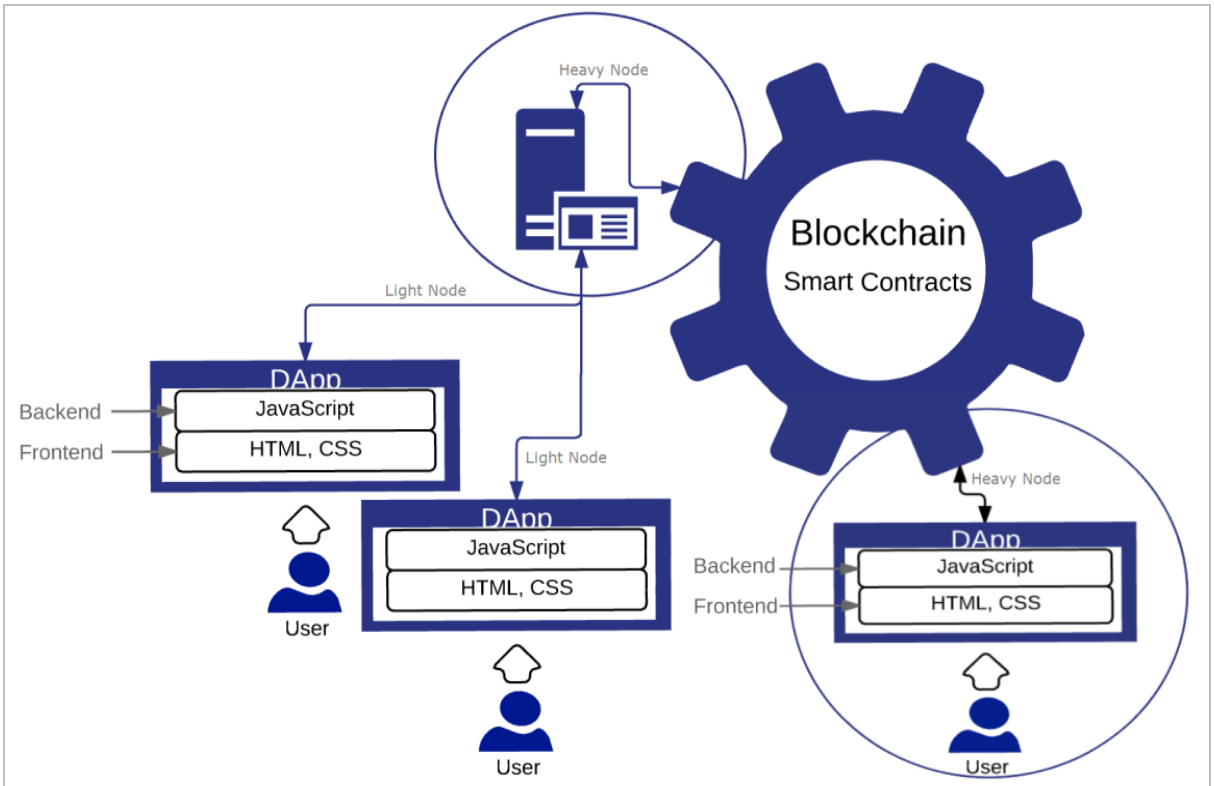

Figure 1. Core Components of a Blockchain System

databases are considered to be most reliable and most important in legal disputes.

In short, the essence of the apparent problem in the maritime shipping industry's situation is that there is no *single source of truth*, which thereby causes substantial legal problems and economic losses. Thus, our paper pursues a problem-centric design science approach (see Appendix B) to overcoming this issue. Our solution proposes a blockchain prototype and illustrates the associated decision path necessary for selecting the proper system solution. The general decision steps we describe can also be applied to other scenarios beyond the maritime shipping industry.

Basic Business Deliberations About Blockchain Technologies

In essence, blockchain is a distributed transactional database that is shared among multiple actors (see Figure 1). In order to perform a transaction, users reference each other through their public keys and use their private keys for cryptographically signing transactions.[17] Each successful transaction on the blockchain indicates an update to the database that is replicated and stored by each participant. These transactions are aggregated and appended to the database in blocks.[18] These transactions can be automatically managed through smart

[17] Glaser, F., op. cit., 2017.

[18] Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., and Rimba, P., op. cit., 2017.

contracts. Smart contracts are pieces of code that implement a business logic by transitioning the current database state to the next state. Services that are based on one or more smart contracts are called *decentralized applications* (DApps).[19,20] The essential blockchain benefits derived from these functionalities include its immutability, nonrepudiation, data integrity, transparency, and the potential for equal rights of its participants.[21]

Blockchain systems are commonly distinguished in terms of public or private access to reading blockchain data and the permissioned or permissionless rights to validate data (see Appendix A). Despite the assumed potential of blockchain technologies for revolutionizing the economy at large,[22] it also has technical limitations compared with other distributed databases that must be acknowledged when considering a blockchain solution (i.e., capacity, latency, privacy).[23,24]

THE BLOCKCHAIN DECISION PATH: A DESIGN SCIENCE APPROACH

We developed our ten-step decision path by reviewing different blockchain decision paths from public media and practitioners,[25,26] and by discussing blockchain design decisions with two stakeholders and integrating them with the authors' professional experience in blockchain consulting. The respondents (see Appendix C) included a potential system user (an experienced pilot from Denmark's biggest pilotage company) and a potential system owner associated with the Danish Maritime Authority (also an experienced ship inspector at the Nautical Institution).

We articulate our ten-step decision path as a series of questions: The first seven increasingly specific questions concern whether or not the use of blockchain would be useful and feasible; the last three questions are intended to help determine which blockchain type would be appropriate for the respective business case (see Appendix A). In the following, we will

describe each step, outline potential alternatives to blockchain solutions, and illustrate the individual decisions by applying them to the case of the maritime shipping industry.

1. Is there a need for a shared common database?

It is important to remember that despite all its various fields of application, blockchain is a database at its core.[27] Thus, the first decision when considering whether to use a blockchain system is whether a database is needed to provide the required service at all, and, if so, whether a traditional database

[19] Lacity, M. C. 2018. "Action Principles for Enterprise Blockchain Applications," *MIS Quarterly Executive*, forthcoming.

[20] Glaser, F., op. cit., 2017.

[21] Xu, X., et. al., op. cit., 2017.

[22] Beck, R., Stenum Czepluch, J., Lollike, N., and Malone, S. 2016. "Blockchain-the Gateway to Trust-Free Cryptographic Transactions," *24th European Conference on Information Systems (ECIS)*, İstanbul,Turkey. AIS.

[23] Glaser, F., op. cit., 2017..

[24] Xu, X.,et. al., op. cit., 2017.

[25] Meunier, S. 2018. "When Do You Need Blockchain? Decision Models." Retrieved May 21, 2018, from https://medium.com/@sbmeunier/when-do-you-need-blockchain-decision-models-a5c40e7c9ba1

[26] Zubko, H., and Bohner, T. 2018. "Lessons Learned from Hyperledger Fabric Poc Projects." Retrieved May 21, 2018, from https://cn.hyperledger.org/blog/2018/04/19/lessons-learned-from-hyperledger-fabric-poc-projects

[27] Glaser, F., op. cit., 2017.

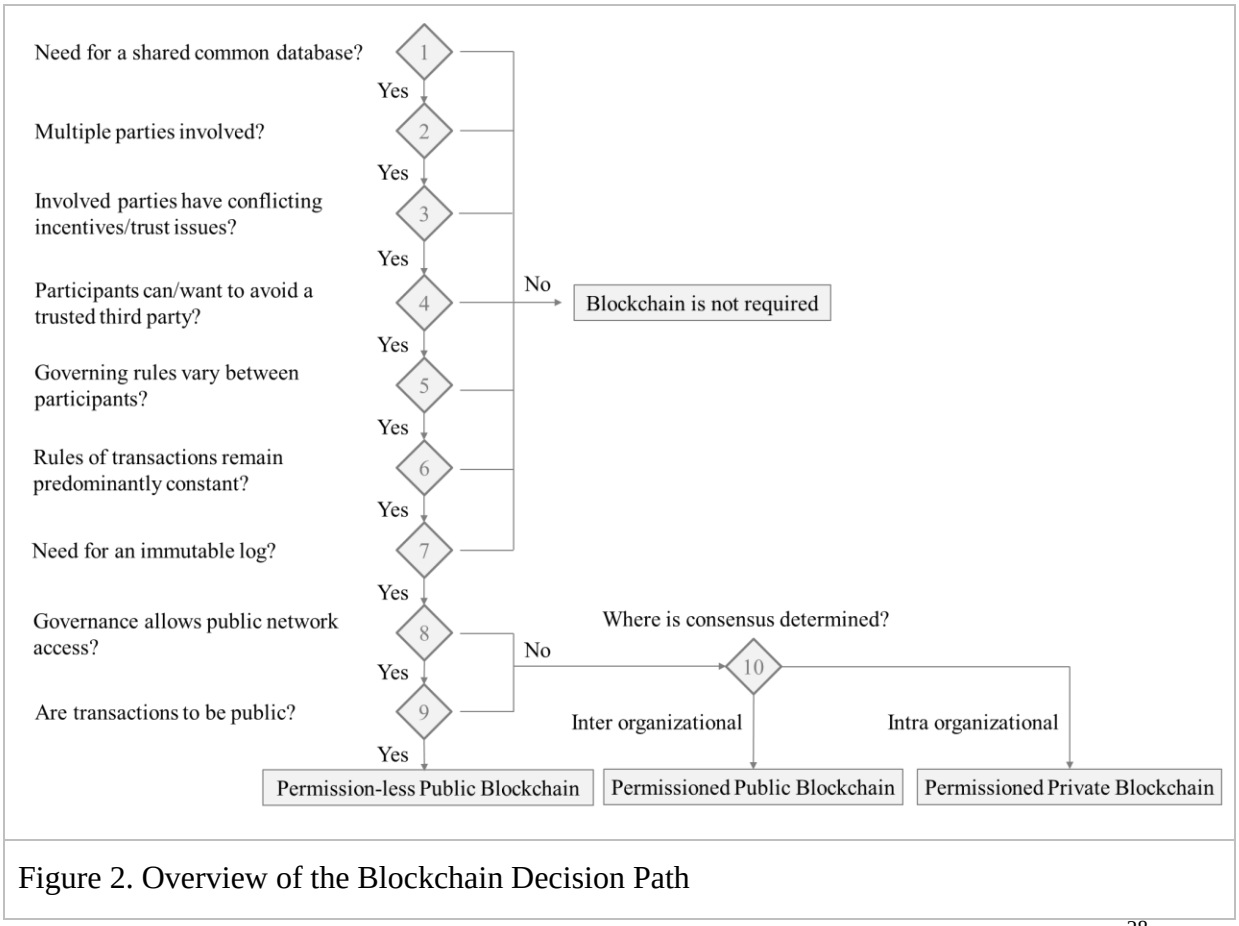

Figure 2. Overview of the Blockchain Decision Path

may already adequately serve the organizational needs. In such cases, it would be advisable to simply use established technologies to store data and manage transactions, instead of using a blockchain.

In the case of the maritime shipping industry, each vessel weighing over 100 gross tonnages receives a unique seven-digit international identification number issued by the International Maritime Organization (IMO-code). This number can be traced back to the year 1987 and was implemented to increase safety and reduce fraud. The International Maritime Organization (IMO) is an agency of the United Nations and is the authority which sets the standards for safety and acceptable shipping pollution.[28] The frequent need to exchange data among multiple entities, and the long history of different types of data storage relating to a vessel associated with an IMO-code, are all factors indicating a strong need for a database. In essence, various entities hold, edit and access different kinds of data about each vessel (see Figure 3). These data are of various types and are stored in various formats (i.e., physical and digital). Moreover, the data are owned by different actors, whose operations depend on the exchange of these data:

[28] International Maritime Organization, 2013. "IMO What It Is." Retrieved June 11, 2018, from http://www.imo.org/en/About/Documents/What%20it%20is%20Oct%202013_Web.pdf

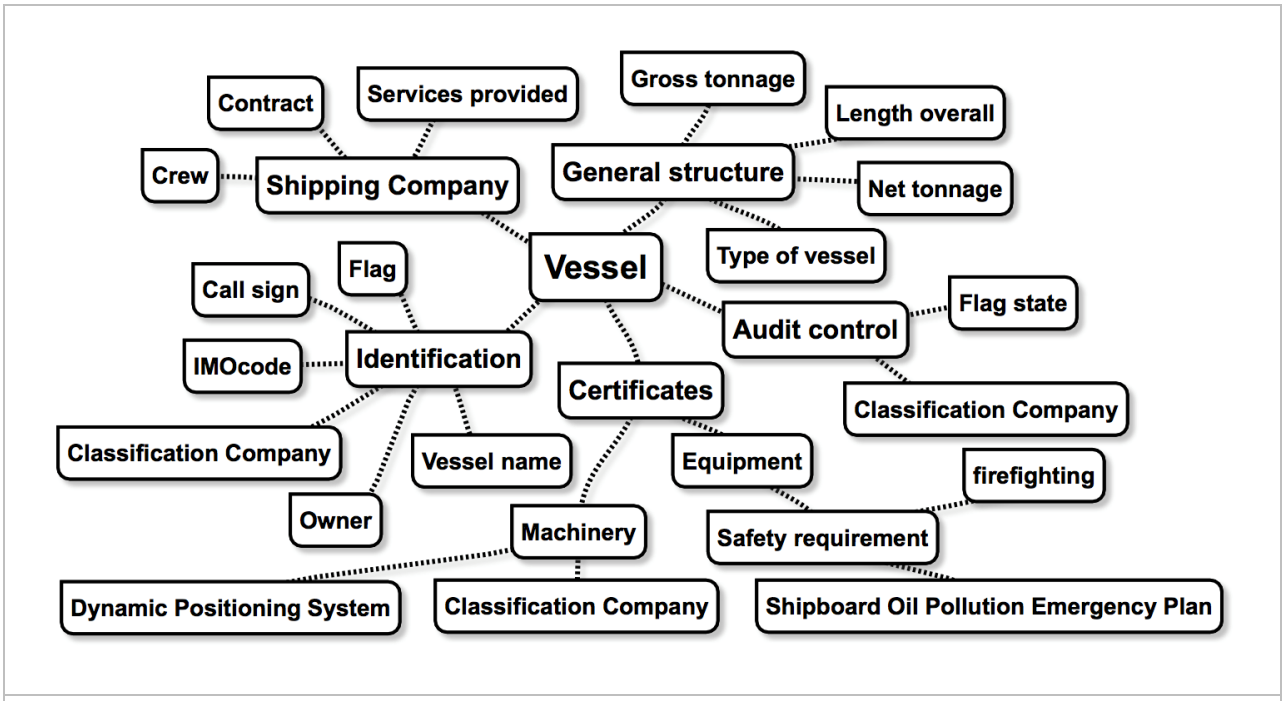

Figure 3. Overview over the Diverse Information Affiliated with a Vessel

In the case of the maritime shipping industry, each vessel weighing over 100 gross tonnages receives a unique seven-digit international identification number issued by the International Maritime Organization (IMO-code). This number can be traced back to the year 1987 and was implemented to increase safety and reduce fraud. The International Maritime Organization (IMO) is an agency of the United Nations and is the authority which sets the standards for safety and acceptable shipping pollution.[29] The frequent need to exchange data among multiple entities, and the long history of different types of data storage relating to a vessel associated with an IMO-code, are all factors indicating a strong need for a database. In essence, various entities hold, edit and access different kinds of data about each vessel (see Figure 3). These data are of various types and are stored in various formats (i.e., physical and digital). Moreover, the data are owned by different actors, whose operations depend on the exchange of these data:

Quote 1: *"...then we simply have the blockchain—regardless of what happens, whether it's here at the Danish Maritime Authority or whether its shipping companies, or brokers, or agents, etc.. Every time they do something related to the registry, it's sent through blockchain so everything is updated at once."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

In order to prevent data inconsistency across multiple databases, the maritime shipping industry represents a clear example demonstrating the need for a shared common database.

[29] International Maritime Organization, 2013. "IMO What It Is." Retrieved June 11, 2018, from http://www.imo.org/en/About/Documents/What%20it%20is%20Oct%202013_Web.pdf

At this point, practitioners may also closely consider scalability issues regarding the amount and velocity of data stored on-chain. Currently, storing and exchanging a lot of data on blockchains can become very slow and expensive due to prolonged verification periods and transaction fees. To avoid scalability issues, designers may consider an off-chain database integration to the blockchain system or simply using an ordinary database instead of a blockchain. Since the apparent situation does not require frequent database updates, we do not need to accommodate these scalability concerns.

2. Are multiple parties involved?

In this section we consider the essential blockchain functionalities as a decentralized transactional database.[30] This implies that multiple parties engage with and interact through the system. In the case of blockchain, engagement means that more than one entity contributes, writes, and updates the data. Therefore, the second question that needs to be addressed is whether more than one party is involved with the database. A blockchain system only makes sense if there are multiple actors. Alternatively, a centralized database will provide more efficient service:

Quote 2: *"Blockchain can help us obtain better security when handling documents between different parties. So that those who are in this chain handling documents concerning ships, would be in the loop all the time on these documents"* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

The Nautical Institute (NI) works alongside the IMO as a nongovernmental organization in a consulting role. The NI is a classification company that classifies vessels based on the IMO publication that determines rules for each class for dynamic positioning.[31] The Danish Maritime Authority (SfS) is the national governmental organization responsible for the shipping companies' documentation compliance and its certification requirements for cargo, safety, and medical restrictions.

The classification companies are nongovernmental organizations in charge of technical standards and the maintenance of vessels, and they conduct surveys to ensure that the requirements for machinery and equipment are kept up to date on the basis of their class. If there are accidents, the classification company functions as an insurance company, which demonstrates the quality of a vessel to the owner and the authorities by underwriting it. The owner of a vessel is often the shipping company, but a vessel might also be personally owned; the service area of the vessel determines which certificates and legal requirements it must abide by. The governmental authorities also seek to improve service transparency by providing the general public with open access to information about the vessel. In the case of the maritime shipping industry, it would be thus advisable to use a blockchain system, because there are multiple stakeholders involved (see Figure 4).

[30] Xu, X., et. al., 2017.

[31] The Nautical Institute, 2016. "Strategic Plan, Constitution and Articles of Association." Retrieved June 11, 2018, from https://www.nautinst.org/download.cfm?docid=2DE93AEB-0A7F-41A3-9B53D95DF786E051

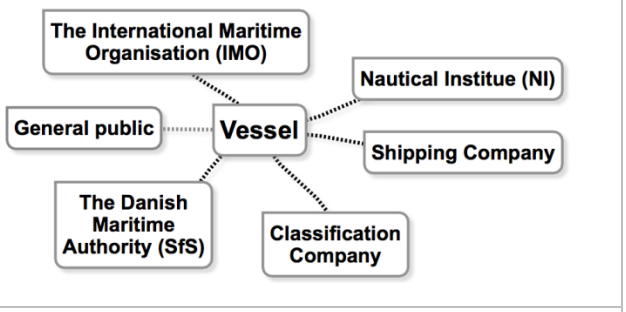

Figure 4. Key Stakeholders Involved

3. Do the involved parties have conflicting incentives and/or are they trusted?

If we have a use case where multiple entities are involved, we need to assess how these entities relate to each other. When you can completely rely on the other parties to provide accurate and reliable information, blockchain databases are not necessary. A trust issue or conflicts of interest between entities, however, propose the application of blockchain technologies. Blockchain has made a name for itself by promising a trust-free economy.[32] Trust in the blockchain is established through the decentralization of data storage and control among participating nodes.[33] This enables autonomously running trust-free services in the form of smart contracts. This means that the tamper-resistant character of

blockchains enables parties to have trust into the validity of data stored on a blockchain instead of trusting the opposite party. Thus, in situations where parties have conflicting interests or the data from the other party cannot be absolutely trusted, blockchain technologies enable automatic data verification and storage to reliably transact. While the trust-free notion admittedly hits its limit when it becomes necessary for blockchain systems to link digital value to physical value through trusted interfaces, in the absence of trust issues the immutable log of transactions would be the only conceivable reason to use blockchain.[34]

Thus, the third question concerns whether trust issues or conflicting interests are present. If there are no trust issues among participants, multiple copies of a centralized database or a managed database with assigned "Create-Read-Update-Delete" (CRUD) rights may offer more feasible solutions. In our maritime shipping case scenario, there are several stakeholders with different and potentially conflicting interests:

Quote 3: *"Of course, there would always be those shipping companies, which might not sail by the highest standards, where the ship does not live up to the best quality. They might not have an interest in open data that is accessible, because then we could simply make a rating list on ships, which would make us capable of choosing more secure ships over less secure ships, if all the data were public."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

[32] Beck, R., et. al., op. cit., 2016.
[33] Xu, X., et. al., op. cit., 2017.
[34] Glaser, F., op. cit., 2017.

The system needs to be able to provide different functionalities for the various stakeholders involved (see Figure 5). On the most basic level, international laws require the system to provide data access to the general public (see Figure 5). The NI must be capable of verifying any vessel's dynamic position class. Furthermore, the IMO and SfS require certification and documentation to confirm the vessels' compliance with (inter)national medical and safety laws. In order to match the data with the vessel, these organizations require the data on technical standards and maintenance from the classification company to be linked with the IMO-code. Furthermore, the SfS and the shipping companies both have an interest in supporting the competitiveness of the shipping companies. Currently, however, shipping companies report dissatisfaction with the processes due to conflicting information from the various sources, lags in communications with authorities, that delay their operations (e.g., booking pilots), and the necessity of reporting the same information back to multiple databases. Conflicting information commonly arises, for example, when both the operator and vendor are listed as owners of a vessel. Communication lags stem from the fact that SfS requires all documents to be physically duplicated in the register to prevent hacking, and requires that at least two people manually check all documents. However,

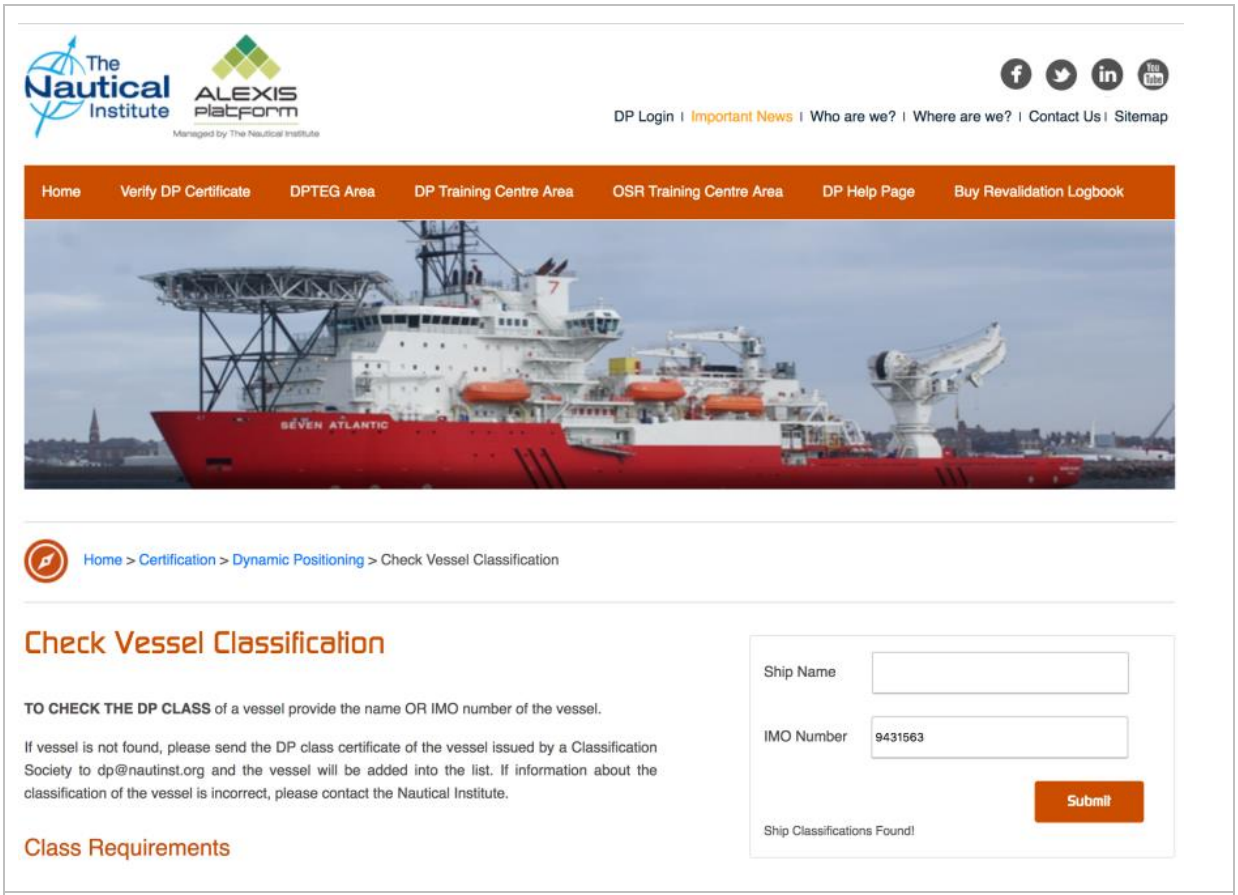

Figure 5. Current Public Access to a Vessel's Dynamic Positioning Information

since foreign shipping companies attempt to defraud by commissioning under different countries' flags, thus circumventing certain expensive legal requirements, a thorough document validation is clearly necessary in this case:

Quote 4: *"...so that those who are in this chain handling documents concerning ships, would be in the loop all the time on these documents, and would not be able to change or fake anything without everyone else knowing it."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

Individual governments levy fines of as much as multiple millions of dollars for these kinds of violations. Thus, potential conflicts of interest, as well as erroneous and conflicting data, demonstrate that information from the different parties involved cannot be trusted. This indicates further need for a blockchain solution to the current process.

4. Can or do the participants want to avoid a trusted third party?

An alternative to the trust relationships between parties is using a trusted third party to manage transactions. One advantage of blockchains systems is that they enable immediate peer-to-peer transactions without relying on a trusted third-party service, such as an escrow service, data feed provider, licensing authority, or notary public. This diminishes the need for a central integration point as a single point of failure that would have the power to control and manipulate a database.[35] Autonomously operating systems, in tandem with the trust-free setup of smart contracts, have the capacity to replace trust intermediaries.[36] In cases where it is not problematic for all participants to use a trusted third-party service provider to process transactions, it is advisable to use these established means of securing transactions.

For the maritime shipping industry, however, there is currently no third-party service provider capable of integrating all sources of information and making them publicly accessible. Indeed, there are considerable trust issues that would preclude the use of a third-party mediator, as well as distinct interest in building a system that does not require such an intermediary:

Quote 5: *"The thing you need to understand is that the banks have so unimaginably little trust in each other, so for anything they do they need to have an intermediary. Even between banks in the same company. It could be banks within Danske Bank, they trust each other so little that they are always using an intermediary. So, there could be a trusted agent in the middle, and it could then be central. And by using blockchain they can try to see if it can eliminate this middle man, and the trust between men."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

Quote 6: *"The challenge occurs when we have international stakeholders, where we need to validate their identity, and [need to validate] who these people are. It sometimes happens that the person who is employed by a company needs to go to a notary to prove that, in fact he is the correct person. But this is not enough, the two people can actually be asked to go hand-in-hand to the embassy, who confirms that the notary is actually a reputable notary and that everything is ok."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

As such, a blockchain-based solution seems feasible and desirable in this case.

[35] Xu, X., et. al., op. cit., 2017.

[36] Glaser, F., op. cit., 2017.

5. Do the governing rules differ between some participants?

After establishing that multiple parties with potentially conflicting interests or existent compliance concerns are involved, it is necessary to consider whether these individual actors require different access rights within the system. The blockchain architectural design allows for distinguishing rights for data reading and writing, as well as access validation rights.[37] Furthermore, on the application layer, smart contracts can govern different privileges in terms of asset issuers (e.g., releasing tokens), account managers (e.g., controlling and exchanging tokens), or observers (e.g., receiving and viewing transactions).[38] If a system does not require different access rights for different individuals, a relational database offer a more feasible alternative.

In our maritime shipping case, the various stakeholders hold and require different types of access rights:

Quote 7: *"Mærsk, for example, they may be allowed to go in and do some things in blockchain, using some governance rights. That's one of the things [among others like the guarantee of information validity and source identity]."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

For example, IMO gives the vessels an IMO-code, while the NI distributes the license given to each vessel, and SfS is in charge of the registry, etc. Lastly, the general citizen needs to be able to access information about the vessel. The different rights of the various stakeholders indicate that the rules governing system participants are not uniform, which would thus argue for the benefits of using a blockchain system.

6. Do the rules of transacting remain predominantly constant?

Next, it must be determined whether the different rules of transacting change frequently. For blockchains it is difficult to accommodate change due to their consensus-based decision-making procedures.[39, 40]

Smart contracts that provide blockchain-based services are autonomously executed,[41] making them very difficult to change or update.[42] So, in systems where transaction rules change frequently, it would be inadvisable to use blockchain.

In the case of the maritime shipping industry, the basic informational requirements do not change. Thus, the data that would be necessary for smart contracts to update and retrieve vessel information could be standardized (see Figure 6):

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[37] Xu, X.,et. al., op. cit., 2017.

[38] Chain.com. 2018. "Participating in a Blockchain." Retrieved May 23, 2018, from https://chain.com/docs/1.2/core/learn-more/blockchain-participants

[39] There are examples of such changes in decision-making. For example, following the siphoning of decentralized autonomous organization (DAO) tokens through an exploited code bug, there was a DAO hard fork on Ethereum, leading to a heavily disputed but ultimately successful change to decision-making. However, regarding Bitcoin, the stakeholders' inability to agree on a hard fork to solve scaling issues has led to a so-called governance crisis.

[40] Murck, P. 2017. "Who Controls the Blockchain?", *Harvard Business Review, 19 (1*).

[41] Glaser, F., op. cit., 2017.

[42] Grincalaitis, M. 2018. "Can a Smart Contract Be Upgraded/Modified? Is Cpu Mining Even Worth the Ether? The Top Questions Answered Here…." Retrieved May 20, 2018, from https://medium.com/@merunasgrincalaitis/can-a-smart-contract-be-upgraded-modified-1393e9b507a

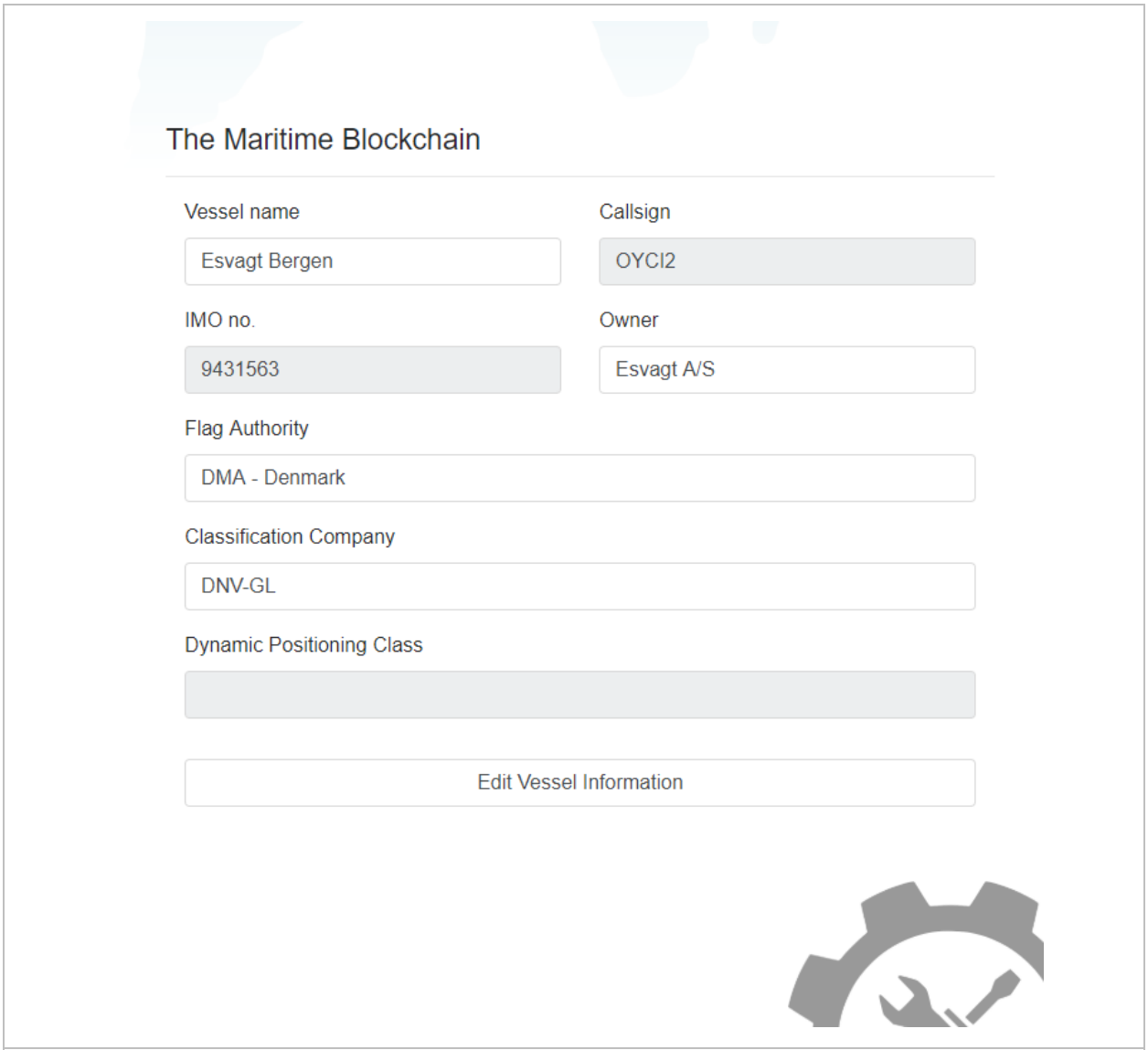

Figure 6. The Proof of Concept Illustrating the Input Requirements for the System's Smart Contract

Quote 8: *"The ship registry can be compared to how the registry of land is conducted. In our registry it is just registration of ships instead of houses, where it depends on how big its bruttoregister tonnage is."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

Thus, we believe that a blockchain-based solution would be feasible in this case.

7. Is there a need for an objective, immutable log?

The essential benefits commonly shared by different types of blockchains include the immutability and integrity of a nonrepudiable log of transparent transactions.[43] The tamperproof log of

[43] Xu, X.,et. al., op. cit., 2017.

historical transactions is particularly helpful for auditability purposes.[44] A blockchain not only stores current information but also maintains a log of its history.

In contrast, creating an auditable history involving paper records is much more difficult. Not only must authenticity be guaranteed by physical seals and signs—which, however, can never be entirely trustworthy—but papers or databases relying on human input are also prone to human error, especially when transactions must be manually handled on a regular basis.[45] If a system does not require the guaranteed validity of transactions, and does not need a definitive validation of transaction details, such as time stamps and parties involved, then regular databases may present a simpler solution for managing the data flux.

However, in the case of the maritime shipping industry, since 1987 international maritime law has required that all relevant information about any large carrier vessel above 100 gross tonnages is stored in a way that is auditable in order to increase safety and prevent fraud:

Quote 9: *"But additionally we also have the benefits of the entire audit trail and the document flow by using the blockchain technologies, or at least the philosophy behind it."*— project manager and nautical advisor, the Danish Maritime Authority (SFS)

As a medium-sized Danish pilotage company with approximately 20,000 pilotages a year, DanPilot has roughly 55 obligatory data searches per day. The company has had to hire 50 administrative staff members (approximately 20% of their workforce) to manage the legal requirements regarding data in the current system. Since, however, all international authorities have their own disconnected databases and individual specifications, pilots also have to double-check all information in order to reasonably demonstrate that the company is obeying all the many laws. SfS confirms that even though a pilot may be given wrong, invalid, or incomplete data, it is his or her personal responsibility—and license that is at stake—if something goes wrong. The administrative violations that inevitably do occasionally occur frequently cause multi-million dollar fees due to delayed cargo clearing, additional docking fees, and contract penalties.[46]

Furthermore, SfS makes its vessel register publicly accessible through a separate database on its webpage (see Figure 7), which is not its official register and may contain outdated, altered, or missing information. Searching this public register requires specific knowledge of a vessel—for example, call-sign, ship name or IMO-code. All three types of information are unique identifiers of a vessel and, depending on the flag or organization, the identifier may change:

Quote 10: *"...and if you dig into the data, trying to figure out why only the Danish Maritime Authority has it (Esvagt Bergen) as a cargoship and not a stand-by ship, in relation to how it is built from the classification companies, and in relation to how it is operated, it will become very confusing. But this is*

[44] Glaser, F., op. cit., 2017.

[45] Bauerle, N., and Kuznetsov, M. 2018. "Why Use a Blockchain?" Retrieved May 20, 2018, 2018, from https://www.coindesk.com/information/why-use-a-blockchain/

[46] Pittalis, E., et. al., op. cit., 2018.

where I think blockchain can offer the absolute truth." — pilot and expert judge, DanPilot A/S

Considering the fluctuating and highly documented nature of shipping operations—which, however, depend on often not entirely trustworthy information—an objective and immutable log in form of a blockchain would seem to be a most desirable development:

Quote 11: *"…but again, it has to do with insurance and demands. It is something legal, and I am not for one second in doubt that this [blockchain prototype] could be used to exchange information easily and smoothly.*"— project manager and nautical advisor, the Danish Maritime Authority (SFS)

8. Does governance allow public network access?

At this point, since all these questions have been answered in favor of blockchain use for the maritime shipping industry, it would seem that we have a valid use case for a blockchain database. As a next step, will be necessary to assess whether a permissioned or permissionless blockchain should be used. To that end, it first needs to be determined whether a governance mechanism that controls access to and participation in the network is necessary. Control functionalities in a blockchain environment refer to whether or not there is a need for managing writing rights on a blockchain. On a permissionless blockchain, new users can join anytime; they can validate and transmit transactions, as well as append or mine blocks. Permissioned blockchains only allow preregistered nodes to validate transactions.[47,48] Permissioned blockchains are more suitable for regulated industries or use cases that have "know-your-customer" regulations. The permission information can be stored either on- or off-chain.[49]

In the case of the maritime shipping industry, different stakeholders have different rights within the system:

Quote 12: *"We have all the different stakeholders segmented into categories, which will require some kind of access control to get into the system, like a protected (permissioned) blockchain."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

While the general public only needs to read the data, other stakeholders have various writing rights for their distinct data responsibilities. Thus, our case example would require some type of permissioned blockchain to account for these versatile rights. To increase the system's ease of use, we decided to make the prototype available to heavy and light nodes (see Appendix B).[50]

[47] Beck, R., et al., op. cit., 2018..

[48] Peters, G. W., and Panayi, E. 2016. "Understanding Modern Banking Ledgers through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money," in *Banking Beyond Banks and Money*. Springer, pp. 239-278.

[49] Swanson, T. 2015. "Consensus-as-a-Service: A Brief Report on the Emergence of Permissioned, Distributed Ledger Systems." *Report* 4. Retrieved July 21, 2017, from http://www.ofnumbers.com/wp-content/uploads/2015/04/Permissioned-distributed-ledgers.pdf

[50] Clients using the heavy node download the entire blockchain platform and need to download every new block before a correct updated output is reliable. This will enable the authorities and shipping companies to prevent fraudulent database manipulations. The light nodes do not store the entire blockchain but enable efficient reading access to the blockchain system.

9. Are transactions public?

After writing rights are determined, it becomes necessary to decide who will be allowed to read blockchain data.[51] If the transactions can be viewed publicly, a public blockchain like Bitcoin or Ethereum would be the system of choice. However, regulating reading access requires a private blockchain system like IBM's Hyperledger Fabric.

As mentioned earlier, in the present case scenario, the general citizenry only requires reading access, while the remaining stakeholders have different writing rights:

Quote 13: *"In the ship registry there is no confidence information, everything is publicly available, which is one of the things a new (blockchain) ship registry should provide as open data."* — project manager and nautical advisor, the Danish Maritime Authority (SFS)

Therefore, a permissioned public blockchain that checks individual rights when logging a transaction (i.e., creating or updating data) or call request (i.e., reading data) through the individual's public key (see Figure 7) would be the appropriate system to employ. Such a system would allow for the disentangling of reading (i.e., general citizen) and writing rights (i.e., shipping companies, classification companies, flag-states, IMO, NI) of the different stakeholders.

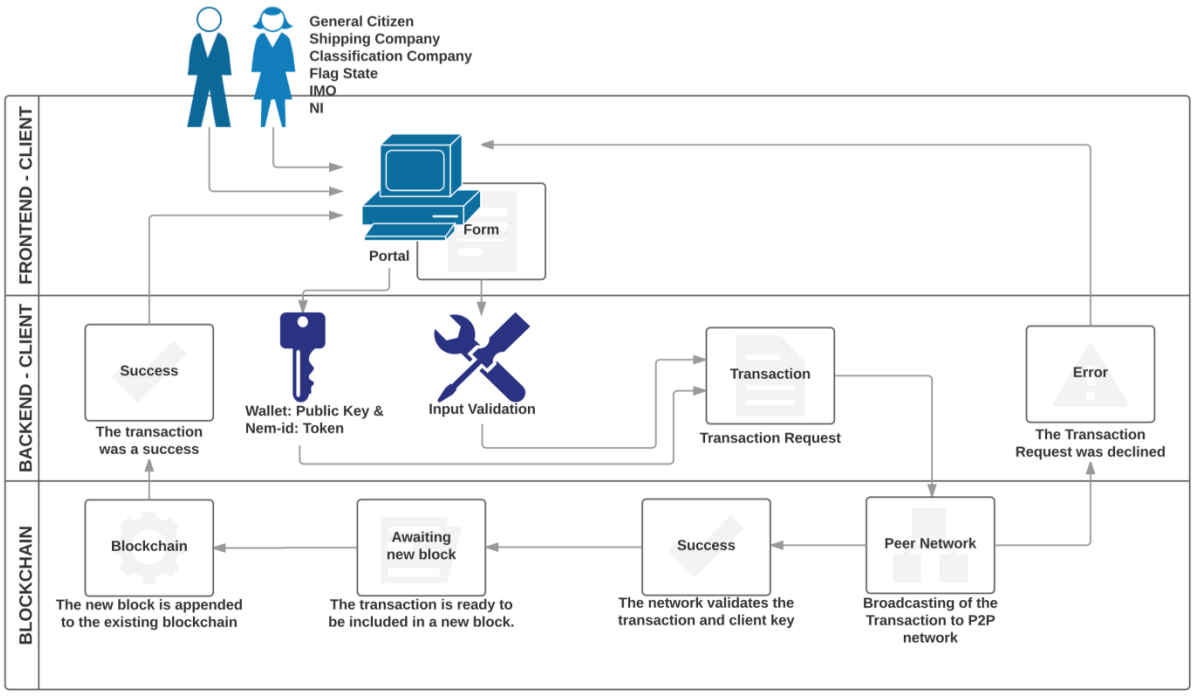

Figure 7. Detailed Prototype Mode of Operations

[51] Beck, R., et al., op. cit., 2018.

10. Where is the consensus determined?

If reading and/or writing access needs to be limited, a permissioned blockchain would be required. As such, one or more authorities could act as a gatekeeper for participation. These authorities could determine who may join a network (and read information), initiate transactions, or mine blocks.[52] There are two emergent types of permissioned blockchains that are based on how the consensus for the validity of transactions is determined: private and public.

Private permissioned blockchains determine the validity of transactions within the organization. Examples include the permissioned private blockchain of IBM's Hyperledger Fabric and R3's Corda. As such, Hyperledger Fabric, for example, does not require computationally intensive mining, but relies on a consensus mechanism of trusted validating peer nodes that multicasts the transaction request to all other validating peers to reach consensus and ultimately execute transactions.[53]

Public permissioned blockchains have more finely differentiated rights.[54] This type of blockchain is also sometimes referred to as a hybrid blockchain.[55] where consensus is established between participating organizations. Examples of this type of blockchain include Ripple, Multichain, Eris, or the adoption of the private iteration of Ethereum. It should be noted that public permissioned blockchains also have a consensus mechanism. The two types of permissioned blockchains differ only in terms of the locus of consensus determination.

CONCLUSION: CLOSELY CONSIDER WHETHER YOU ACTUALLY HAVE A BLOCKCHAIN-USE CASE

We provide a step-by-step decision path that managers can follow to identify whether or not they have a blockchain-use case, which alternatives to blockchain they should consider, or which kind of blockchain to use. This series of simple yes-no questions should be informative for practitioners helping them make sense of the challenges and design perimeters. In reality, however, design is much more than binary decisions, and much more about complex and possibly paradoxical trade-offs. These trade-offs can be localized to the actual design characteristics, also relate much broader to business requirements and –constraints.[56]

Thus, practitioners need to carefully evaluate the feasibility of different business requirements and design solutions. For example, if there are pressing regulatory requirements for an auditable and immutable log (decision step 7), a blockchain solution might be advisable regardless of the other decision steps. As a rule of thumb, we usually advise that on average at least 5 out of the initial 7 questions need to be

[52] Xu, X., et. al., op. cit., 2017.

[53] Castro, M., and Liskov, B. 1999. "Practical Byzantine Fault Tolerance," *3rd Symposium on Operating Systems Design and Implementation (OSDI)*, pp. 173-186.

[54] Xu, X., et. al., op. cit., 2017.

[55] Glaser, F., op. cit.

[56] Andriopoulos, C., and Lewis, M. W. op. cit., 2010.

answered with “yes” to consider a blockchain solution. But again, for each individual case practitioners need to carefully balance various potentially paradoxical business and design requirements.

We illustrate the decision path by applying it to the case of the maritime shipping industry, where we develop a blockchain-based prototype to overcome the problem of the absent single source of truth. In this industry, this grievance frequently leads to substantial operational inefficiencies and economic damages through a delayed discharge of cargo, additional docking fees, or tied-up resources like immobilized carriers. Leading shipping companies like Mærsk A/S, APL Ltd., Hyundai Merchant Marine Co., Samsung SDS Co. have already invested heavily in blockchain technologies in hopes of overcoming the paper-laden processes. Doing this, they believe, would generate an additional US$1 trillion in trade.[57]

A shipping company employee from our sample estimates that the development and roll-out costs for a blockchain system would be well below the fees associated with just one of the frequently occurring cargo clearance delays. Since the apparent issues surrounding inefficient processes using partly paper-based documentation, redundant data storage, and insufficient communication are certainly not specific to this industry, we assume that managers in other industries will also benefit from the decision-path outlined here.

[57] Park, K., op. cit., 2018.

APPENDIX A: THE THREE DIFFERENT TYPES OF BLOCKCHAINS

The blockchain decision path consists of ten steps, with the last three helping to determine which type blockchain type should be used in the respective business-case scenario. It is imperative to note that the same blockchain (e.g., Hyperledger Fabric's) has the capacity to assume different types of blockchains (e.g., permissioned public and permissioned private). The answers to the last three steps of our decision path will result in one of the following options (see Table 1):

- The *permissionless public blockchain* type is an open network and enables everyone to join (e.g., Bitcoin, Ethereum). It is possible for all users to read, write, and verify transactions on this type of blockchain. This type of blockchain can be applied to replace the role of trust in a third party. Trust is built between peers in the network because they all have to abide by the established consensus mechanism. The most popular consensus mechanism is Proof of Work (PoW) and Proof of Stake (PoS). In a PoW system, miners in the network compete computationwise by solving the hash function of the next block. PoS defines the next valid block in a more deterministic way, depending on the stake that different miners hold (e.g., number of tokens).
- The *permissioned public blockchain* type is a closed network, were only verified and trusted nodes can participate (e.g., Ripple, Multichain, Eris, Hyperledger Fabric). It is also called a "hybrid blockchain," because all participants can view the data, but only authorized users can validate transactions.[58] Users are authorized through a network consensus after providing the respectively necessary proof of eligibility. Such a system constitutes an intra- or intergroup technology advancement. However, if there were no trust issues among users in a hybrid blockchain system, the only remaining reason to opt for a blockchain database would be the immutable logging of historical transactions for auditability purposes.[59]
- The *permissioned private blockchain* type is a closed network (e.g., Hyperledger Fabric, Corda), that allows only authorized users to read, submit, and validate transactions.[60] Transactions are verified or the blockchain's consensus is determined within an organization. Commonly, a Practical Byzantine Fault Tolerance (pBFT) protocol is used, which requires a certain percentage of previously verified nodes to confirm the transactions. This makes the pBFT model more efficient than PoW as the miners are not competing and only doing the computations to benefit the network.

[58] Beck, R.,et. al., op. cit., 2018..
[59] Glaser, F., op. cit., 2017.
[60] Beck, R., et. al., op. cit., 2018.

Table 1: Description of the Three Blockchain Types	
Blockchain Type	**Properties**
Permissionless public blockchain	Anyone can join the network, read, write, and verify transactions through Proof of Work or Proof of Stake.
Permissioned public blockchain	Only trusted and validated peer nodes may join the network. The consensus is determined between participating organizations.
Permissioned private blockchain	Only trusted and validated peer nodes may join the network. The consensus is determined within an organization through, for example, a Practical Byzantine Fault Tolerance algorithm.

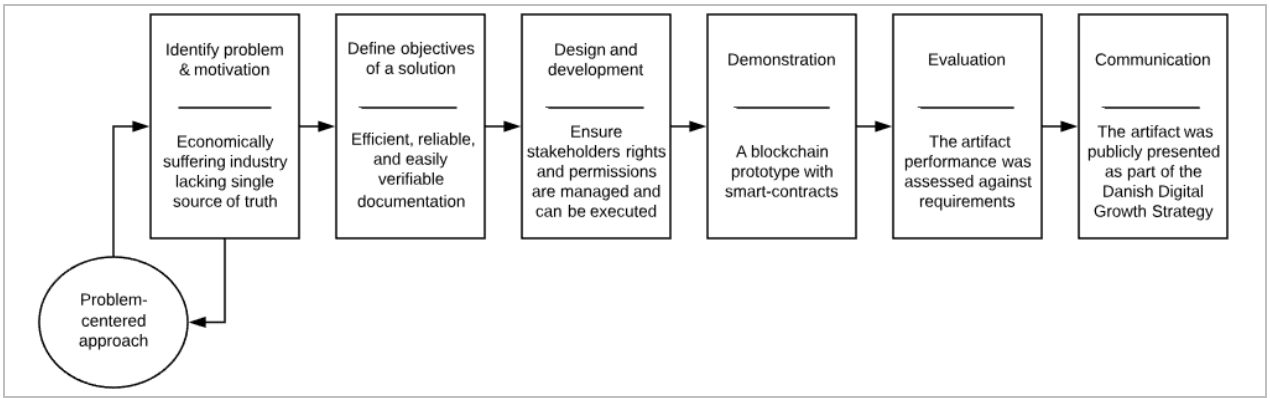

Figure 8. Problem-Centered Design Science Approach

APPENDIX B: THE RESEARCH APPROACH

This research applies a problem-centered design science research approach developing a Proof of Concept (PoC), optimizing and addressing the needs of the industry through the development of an artifact (see Figure 8).[61]

The Problem-Centered Solution

The maritime shipping industry is currently undergoing economically challenging times. This has encouraged stakeholders across this industry to reconsider their processes and opportunities. Most of the current administrative processes require a lot of human attention, causing inefficiencies, errors, and delay that can lead to considerable economic damages. This problem is caused by the lack of a single source of truth. The goal of this study was to overcome the prevailing problems.

Identify Problem & Motivation

The essence of the problem discovered is that there is no single source of truth that is accessible in the maritime shipping industry, which leads to fines and allows companies to forge documentation, avoid proper occupational health regulations, and circumvent legal requirements.

Objective of the Solution

We approached the maritime shipping industry as a context for exploring the use of blockchain through conducting interviews. To overcome the problem engendered by the lack of a single source of truth, a blockchain prototype was to be developed, along with the associated decision path selecting the proper system solution. The main objectives of the prototype were to improve the efficiency of administrative processes, to make them, more reliable and trustworthy, and to make documents more easily verifiable. We conducted interviews before developing the prototype, in order to ensure that we were choosing the most appropriate and most beneficial solution (see Table 2).

[61] Ken Peffers, Tuure Tuunanen, Marcus A. Rothenberger, Samir Chatterjee, 2007-08. "A Design Science Research Methodology for Information System Research" *Journal of Management Information Systems, 24:3,* pp 45-78.

Design and Development

The entire system must be able to provide public data to clients accessing the platform, as well as the specific permissions demanded by each client for logging changes. In order to accommodate different reading and writing rights, we opted for a public permissioned blockchain on the Ethereum private net. The PoC was based on the design from the mock-up and wireframe simulating a data update transaction by a stakeholder or a call for information by a reader.[62] The national maritime authorities could initially serve as superusers, managing permission rights.

Stakeholders can access the blockchain either through a heavy or light node depending on whether or not writing rights are required or permitted.

Demonstration

We demonstrated the design, development and benefits of the blockchain solution for the SfS.

The demonstration showed the feasibility of the developed blockchain solution across the entire maritime shipping industry. Meanwhile, the general public would be able to follow the state of the ship registry as it changed when smart contracts were signed and executed. The smart contract was written with the programming language Solidity.

The insights gained from the design decisions during the development of the prototype served as a foundation for the blockchain decision path.

Evaluation

A third interview with SfS evaluated the blockchain PoC solution in terms of the qualities and requirements gathered from the industry in the first and second interviews. The relative assessment of the blockchain PoC design and development, in the light of the demonstration, was that it was consistent with the actual needs and constraints of the industry.

Communication

The contribution of this effort was discussed with blockchain consultants, along with the use of the blockchain decision path. Furthermore, in the early 2018 the Danish government published a strategy for the Danish digital growth,[63] stating that the Danish government wishes to use a blockchain-powered solution for their ship register in the public sector.

Contribution

The study's research artifact contributes a designed and developed blockchain PoC on the basis of the interviews with individuals working with the maritime shipping industry. This artifact provides a suitable and effective solution for solving the problem-centered issue we focused and for establishing one single source of truth, throughout the maritime shipping industry.

[62] The Interactive Prototype can be accessed at https://projects.invisionapp.com/share/7KBLNHNTZ#/screens/232477611

[63] https://www.regeringen.dk/media/4766/strategi-for-danmarks-digitale-vaekst_online.pdf, pp. 47-49

APPENDIX C: THE INTERVIEWED RESPONDENTS

The following respondents were interviewed to inform and validate the prototype's business requirements and system design.

Table 2: Case-Related Expertise from the Respondents

Organization	Case Description	Case-Related Expertise
The Danish Maritime Authority (SFS)	The Danish maritime authority is the national governmental organization responsible for the shipping companies' compliance to documentation and certification requirements for cargo, safety, and medical restrictions.	*Project Manager and Nautical Advisor* • Holds a Master of Public Administration degree. • 7 years as a senior consultant at The Danish Maritime Authority. • 5 years as a ship inspector at the Danish Maritime Safety Administration.
DanPilot A/S	DanPilot is a medium-sized Danish pilotage company which employs about 160 pilots and 90 boatmen, completing approximately 20,000 pilotages a year.	*Pilot and Expert Judge* • Master Mariner at SIMAC. • 10 years' experience as a pilot at Danpilot. • 3 years as an expert judge in the Danish court system. • 10 years as an officer at Mærsk Supply Service. • 3 years as a superintendent at DCSO.